The impact of floral resources on syrphid performance and cabbage aphid biological control

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Abstract:
We investigated the impact of floral resources on syrphid fitness parameters and on biological control of cabbage aphids. The work led us to the following conclusions:

Honeydew of cabbage aphids enhances the survival of the hoverfly *Episyrphus balteatus*, and can be an important food source when the syrphids are searching within the crop for oviposition sites.

Syrphids can only reproduce when pollen is available as well. Feeding on pollen and nectar during the pre-ovipositional period allows the females to produce eggs for a week thereafter, even when flowers are no longer available. This shows that they can store their food reserves for several days. Female syrphids probably focuses on flower foraging during the first week after emergence, before switching to searching for aphids and oviposition sites (in the crop). Thereafter, the syrphid will have to travel again between floral patches and aphid patches to maintain egg maturation.

Cage experiments show that the syrphid *E. balteatus* can be an effective predator of cabbage aphids on Brussels sprouts. The resurgence of the cabbage aphids in autumn, when natural enemies such as syrphids virtually disappear, suggests that these natural enemies play an important role in keeping the aphids under control during summer.

Syrphids are stimulated in the crop by the vicinity of flowering plants like buckwheat and cornflower. During summer the differences in syrphid densities were not reflected in aphid population levels. Possibly, natural enemies that are less dependent on floral resources, such as parasitoids, compensate for the small scale differences in syrphid predator density.

Keywords: conservation biological control, natural pest control, field margins, companion planting, functional agrobiodiversity, flowers, pollen, nectar, honeydew, predator

Introduction

Many insect carnivores that can play a role in the suppression of pests require nectar or pollen during their adult life stage (Wäckers et al., 2005). The scarcity of flowering plants in modern agricultural fields may therefore prohibit an effective performance of these beneficial insects (Winkler et al., 2005). Providing these floral resources in the agricultural landscape may therefore be an essential element to improving natural control , but may not always be sufficient (Wäckers et al, 2005). As part of a multifarm field experiment in the Netherlands, labelled as the Functional Agro Biodiversity (FAB) project (Van Alebeek et al., this volume), field margins are sown with a crop-specific mixture of annual flowering plants, to provide these floral resources for the natural enemies of our pests (Wäckers et al., this volume).

To optimize the use of flowering field margins, information is required about the biological control agents and their interactions with food sources and pest species. Firstly, we identify which natural enemies can be effective against the economically important pests in the various crops. Secondly, what flowers are attractive for these natural enemies and provide suitable food (Wäckers, 2004). Moreover, we try to avoid flowering plants that are potential weeds, or benefit pest species (Wäckers et al., this volume). Thirdly, we try to establish the optimal spacing and timing of floral resources, while we also address the issue of how margins should be managed to optimize benefits.

Of all field crops studied Brussels sprouts is the most complex in terms of pest control. This is due to the fact that *Brassica* species are attacked by a range of herbivore species (including several aphids, many caterpillars, root flies and thrips), combined with the extended growing season, and the high crop value. Growers therefore typically apply insecticides 5-8 times per season. Of all pests the cabbage aphids (*Brevicoryne brassicae*) are often the most damaging. Biological control of this species can be problematic as it is only attacked by a limited number of aphidophagous species. Lady beetles are rarely seen on this crop and among the generalist aphid parasitoids, this aphid is only parasitized by *Diaeretiella rapae*. In addition, it is attacked by a predaceous gall midge (*Aphidoletes aphidimyza*) and a range of aphidophagous hoverflies (syrphids). Whereas all these species have carnivorous larvae, the adult stages strictly feed on nectar and pollen. Among these species, syrphids are most dependent on floral resources as they require both sugars and pollen in order to produce eggs (Haslett, 1989). Here we investigate the impact of floral resources on syrphid fitness parameters and the impact on biological control.

Lab experiments

To investigate the role of floral resources in the life history of syrphids and in their interaction with cabbage aphids, we conducted a series of experiments in 130 dm^2 gauze cages placed in illuminated climate chambers. As source of floral nectar and pollen we used plants of buckwheat, *Fagopyrum esculentum*. The flowers of these plants are known to be beneficial for several natural enemies (Winkler et al., 2006). Each cage was provided with two small Brussels sprouts plants infested with cabbage aphids, which are used by the female syrphids to oviposit her eggs. We focused on one common aphidophagous syrphid species, *Episyrphus balteatus*. For each experiment fresh pupae from this species were obtained from Koppert B.V. (Berkel and Rodenrijs). Each cage was provided with one newly emerged (<24 hour) female, as well as one or two newly emerged males.

Impact of aphid honeydew and flowers on syrphid survival and reproduction

The impact of aphid honeydew on syrphid survival was studied by varying the level of aphid infestation at the start of the experiment. As a positive control we provided a (1 molar) sucrose solution. The impact of buckwheat flowers was studied under high honeydew levels only, as honeydew is an important trigger for oviposition (Bargen et al. 1998). In addition, we varied the time frame at which the flowers were present: the first 6 days or the full period.

Table 1. Adult survival and female reproduction of *E. balteatus* under different food conditions (22°C, 80% RH)..

Treatment	N (cages)	Mean longevity (days)	% females reproducing
Low honeydew (1 day before, 50 aphids/plant)	8	2.3	0
High honeydew (3 days before, 250 aphids/plant)	6	9.4	0
Low honeydew + sucrose solution (1 molar)	10	15.0	0
High honeydew + buckwheat (1^{st} week only)	10	18.7	60
High honeydew + buckwheat (permanent)	22	21.3	55

Table 1 shows that E. *balteatus* can benefit from a high honeydew level, as this increases its longevity four-fold compared to the low honeydew situation. In the presence of sucrose the longevity increases further. This indicates that honeydew of cabbage aphids is suboptimal as sugar source. The provision of buckwheat, which provides both nectar and pollen, results in a further longevity increase. When the syrphids have these flowers available during their pre-oviposition period only, their longevity was not significantly reduced. This indicates that these syrphids can store their food reserves for several days.

Reproduction clearly occurs only when pollen is available. However, even when buckwheat flowers are permanently present, 45% of the females in the experiment do not produce any eggs. Possibly these females have not mated successfully, or miss the ability or right trigger to oviposit. When flowers are available during the pre-ovipositional period only, the fraction of females that reproduce is not lower, nor the number of eggs produced in the first week of reproduction. In the following two weeks, however, almost no eggs are produced by these females anymore, whereas with flowers oviposition continues, albeit at a lower rate than before. These results suggest that female syrphids can focus on flower foraging during the first week after emergence, and thereafter on foraging for oviposition sites (in the crop). Later, the syrphid will have to travel between floral patches and aphid patches.

Impact of syrphids on cabbage aphid dynamics

To investigate the potential impact of syrphids on cabbage aphids when provided with floral resources, we studied the population dynamics of cabbage aphids on Brussels sprout plants (initially 7 week old, 8 leaves per plant, 2 plants per cage) in cages with or without buckwheat plants. One day before the newly emerged female and male syrphids were put in the cage the number of aphids on the sprouts plants were adjusted to c. 30 per plant.

The results show that in absence of reproducing syrphids the aphid colony growths to 4000 aphids in 3 weeks. In presence of a reproducing female the number of aphids remains low during 3 weeks, resulting in a 7-fold lower aphid population compared with the control. The conclusion is that in the presence of (buckwheat) flowers the offspring of one female syrphid can suppress the growth of an aphid colony during several weeks.

Field experiments

In two successive years field experiments have been conducted at two small non-commercial Brussels sprouts fields of 100 by 24 or 14 meters. At the long western edge of the fields a strip was sown with annual plants. One part was sown with a mixture of flowers that can provide nectar and pollen for different natural enemies (buckwheat, cornflower and borage provided the main flowers from week 25 till week 40). Another part was sown with *Vicia faba* (broad bean or field bean). This species has extrafloral nectaries that are used by parasitoids and predatory beetles, and is functional from week 25 till week 32. The first year the two strips were separated by a strip of short grass, which served as a control.

Syrphid response to flowering field margins

In both years the highest numbers of syrphids were recorded in the second half of July (c. week 29, Figure 1ab). During September the numbers dropped to virtually zero. In both years the mixed flowers (and especially buckwheat and cornflower) attracted much more syrphids than *Vicia faba*. In the mown grass strip almost no syrphids were recorded. *Epysyrphus balteatus* made up about 45% of all syrphids in both years.

Syrphid and cabbage aphid dynamics in the crop

In the crop the number of eggs and larvae of syrphids peaked in week 31 (2005), one week later than the adult syrphids in the flower strip. Thereafter the numbers rapidly declined and were virtually absent beyond mid September. During the whole summer period nearly twice as many syrphid offspring were found in the section adjacent (<4 meter) to the mixed flower strip compared to the other sections. This indicates that syrphids are stimulated by the presence of these flowers.

The difference in syrphid density between field sections did not result in significant different aphid densities (in either year). Possibly, natural enemies less dependent on floral resources, such as parasitoids, compensated for the small scale differences in syrphid density.

On the insecticide-free sprout plants the mean number of cabbage aphids per plant remained below 15 until mid August 2004. After week 34, however, the population expanded rapidly, to exceed 300 aphids in week 40. In 2005, the density of cabbage aphids was higher from the start, but again remained stable throughout the summer period (at c. 40 aphids). After week 35 aphid number started to increase again. The resurgence of the cabbage aphids in autumn when natural enemies, such as syrphids, virtually disappear, suggests that these natural enemies play an important role in keeping the aphids under control during summer.

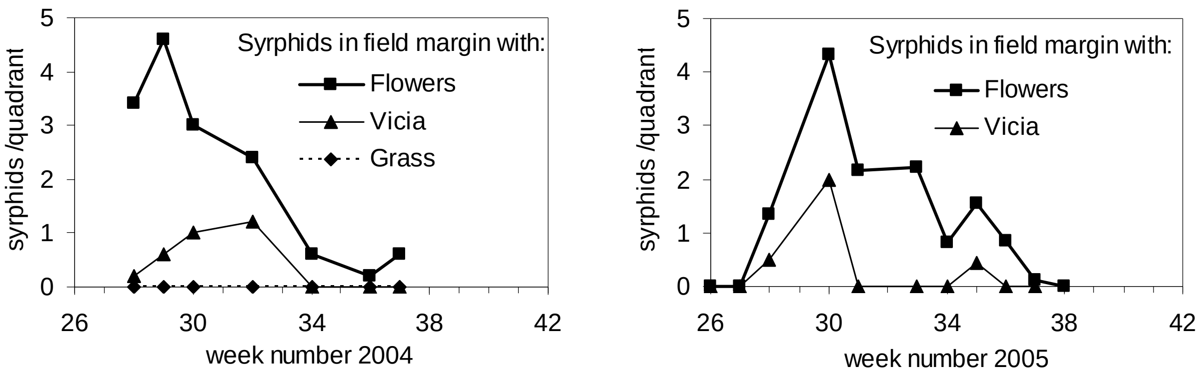

Figure 1ab. Mean number of aphidophagous syrphids per quadrant ($3m^2$) for different field margins in 2004 and 2005.

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